The Analysis, Numerical Simulation, and Diagnosis of Extratropical Weather Systems

Dr. Melvyn A. Shapiro
NOAA/Environmental Technology Laboratory
325 Broadway, Boulder, CO 80303
phone: (303) 497-8965 fax: (303) 497-8181 email: mshapiro@ncar.ucar.edu
Award #: N0001499F0068

LONG-TERM GOAL

My long-term research goal is to contribute to the advancement of the observation, structural analysis, dynamical diagnosis, conceptual model formulation, and numerical prediction of the life cycles of synoptic-scale and mesoscale extratropical weather systems, including the influence of planetary-scale inter-annual and intra-seasonal variability on their evolution. These weather systems include: extratropical oceanic and land-falling cyclones, fronts and their associated cloud, wind, and precipitation systems; upper-level jet streams and clear-air turbulence, extreme topographic flows and their interactions with the ocean.

OBJECTIVES

My research over the past year focused on four primary objectives: i) the synoptic (manual) analysis and four-dimensional data assimilation of field campaign data sets gathered during the Fronts and Atlantic Storm-Track Experiment (FASTEX, 1997), North Pacific Experiment (NORPEX, 1998), and Winter Storm Reconnaissance Program (WSRP 1999), ii) the coordination and design of the of the US Weather Research Program (USWRP) priority research initiative for the optimal mix and implementation of current and next generation operational observing system for improved 1-7 day weather forecasts, iii) the diagnosis and dynamical interpretation of research and operational targeted observations over the North Atlantic and North Pacific oceans, and the impact of these observations on 2-7 day weather forecasts over the North America and western Europe, respectively, and iv) the numerical simulation and observational validation of high-spatial resolution (~10 km) numerical predictions.

APPROACH

My approach toward achieving the above near-term objectives has been to foster scientific interactions between talented scientists and myself, and by doing so, develop the research team required to address these complex objectives. The support that I have received through the current ONR-sponsored grant has been applied, in part, to visits with my collaborators, support for their visits to NOAA/ETL, the publication of our findings, and my presentation of our findings at national and international symposia, universities, and workshops. The following identifies selected tasks and the individuals that I collaborated with in our effort toward achieving the above objectives:

I prepared three-dimensional synoptic analysis of mesoscale field campaign observations of oceanic cyclones, including their mesoscale structure; in collaboration with Nick Bond (NOAA/PMEL). These

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analyses were used to evaluate the realism of mesoscale numerical simulations with the NRL/Coupled Ocean Atmospheric Prediction System(COAMPS) and the Penn. State/NCAR prediction system (MM-5) prepared by Jim Doyle and William Thompson (NRL/Monterey), and Nelson Seaman (Penn. State Univ.), respectively.

I identified the meteorological characteristics of objectively targeted regions within which dropwindsonde observations were deployed during FASTEX, NORPEX, WSRP; in collaboration with Rolf Langland and Ron Gelaro (NRL/Monterey). This task was aimed a communicating the Ameteorological@ characteristics of the theoretical singular vector diagnostics to synoptically oriented researchers and forecasters.

I collaborated with Heini Wernli (ETH/University of Zurich) on idealized numerical simulations of downstream (upstream) baroclinic development and energy dispersion through expanding wave packets. We compared these idealized results with actual examples from the ECMWF operational analyses from the FASTEX, NORPEX, and WSRP objective targeting field campaigns. Our finding and interpretations were used for case study selection and dynamical interpretations of: i) targeted observing studies; in collaboration with Rolf Langland and Ron Gelero (NRL/Monterey), and ii) the four-dimensional data assimilation of satellite and targeted dropwindsonde observations; in collaboration with Xiaolie Zou (Fla. State Univ.), Chris Velden (Univ. Wisc./CIMMS), and Arlin Krueger (NASA/GSFC).

I commanded a leading role in the call to action proposal for the design and implementation of The Northern-Hemispheric Observing System Research and Predictability Experiment (THOR*PEX)*; in collaboration with Rolf Langland (NRL/Monterey). This research initiative is a high priority focus of the US Weather Research Program. It is proposed as an international collaboration between the United States, Europeans Community, Japan and China for the purpose of improving short-range (1B3 day) to extended range (4-10 day) weather forecasts, including a major field experiment in ~2003. This proposal is posted on the USWRP AWhat=s New@ web site (See http://box.mmm.ucar.edu/uswrp).

WORK COMPLETED

The following details the research that I completed this year, those that I collaborated with to accomplish the individual tasks, and whether the results were prepared for publication:

The analysis of adaptive observing strategies from the FASTEX, NORPEX and WSRP targeted observing studies; in collaboration with Zoltan Toth (NOAA/NCEP); Rolf Langland and Ron Gelaro (NRL/Monterey): two journal papers.

Numerical simulations and of arctic mesoscale topographic flows, including: i) the FASTEX IOP-8 breaking lee wave over Greenland, ii) the FASTEX IOP-16 topographically induced low-level jet stream at the southern tip of Greenland, iii) the extreme downslope windstorm over the central mountains of Norway; in collaboration with James Doyle (NRL./Monterey): two journal papers and one conference pre-print.

Numerical simulations and analysis of aircraft observations of US east-coast cyclones: Nelson Seamen (Penn. State U.), Nick Bond (NOAA/PMEL), Paul Chang (NOAA/NESDIS): conference preprint.

The structure, and numerical simulation of low-level oceanic jet streams from FASTEX, NORPEX and WSRP; in collaboration with William Thompson (NRL./Monterey) and Nick Bond (NOAA/PMEL): conference preprint.

The study of idealized and observed downstream (upstream) baroclinic development; in collaboration with Heini Wernli (Univ. Zurich CH): journal paper.

The influence of time-variant mean flows over the North Pacific on extratropical baroclinic life cycles during ENSO; in collaboration with Heini Wernli (Univ. Zurich CH), Nick Bond (PMEL/Univ. Washington): journal paper.

Four-dimensional data assimilation of targeted dropwindsondes and satellite observations of total columnar ozone and cloud- and water-vapor drift winds, from FASTEX, NORPEX, and WSRP; in collaboration with Xiaolei Zou (Fla. State. Univ.), Chris Velden (Univ. Wisc.), and Arlin Krueger (NASA/GSFC).

Analysis and numerical simulation of the fine-scale structure of upper-level jet streams from high-spatial-resolution (~40 km) dropwindsonde observations taken during NORPEX and the Severe Clear-Air Turbulence Colliding with Air Traffic (SCATCAT) turbulence field study; in collaboration with Adrian Marroquin and Cecilia Girz(NOAA/FSL), Diana Bartels (NOAA/FSL) Jim Doyle NRL/Monterey): conference preprint.

The analysis of adaptive observing strategies from FASTEX, NORPEX and WSRP; in collaboration with Rolf Langland, Ron Gelaro (NRL/Monterey): two journal papers. Recent results appear in the Call to Action USWRP AWhat=s New@ web site (See http://box.mmm.ucar.edu/uswrp).

The four-dimensional data assimilation of targeted dropwindsondes, satellite observations of total columnar ozone, and cloud- and water-vapor drift winds into research and operational numerical forecast models; in collaboration with Xiaolei Zou (Fla. State. Univ.), Chris Velden (Univ. Wisc.), and Arlin Krueger (NASA/SCFC).

RESULTS

The following are selected significant results from this year=s efforts:

Our research on the effects of the El Nino Southern Oscillation (ENSO) on extratropical baroclinic life cycles has suggested that the dramatically different time-mean flows between the El Nino and La Nina seasonal climate regimes give rise to significantly different extratropical cyclone structure.

My work on idealized and observed downstream (upstream) baroclinic development with Heini Wernli was incorporated into the interpretation of targeted observing research at NRL/Monterey. Our recent findings show that initial forecast model analysis errors over western Asia and east of Japan can effect the forecasts of land-falling US west coast storms on time scales ~48-72 h, and impact European forecasts ~4-7 days. It was these results that led to the western expansion of the THOR*PEX* observing domain to eastern Asia and the far western Pacific.

Our research on arctic mesoscale flows has led to the documentation and mesoscale simulation

(COAMPS) of the 50 m s^{-1} boundary-layer jet stream that extends ~1000 km eastward from the southern tip of Greenland. The surface thermodynamic fluxes and extreme surface stress on the ocean surface during these events is not resolved in the current climate models.

IMPACT/APPLICATION

The above described work that my collaborators and I have been carrying out is at the frontiers of meteorological research and operational forecasting. We have made contributions on problems in the areas of: i) inter-annual climate variability impacts on extratropical cyclones, ii) targeted observing strategies, iii) arctic mesoscale flows, and four-dimensional data assimilation. The presentation of our findings in the articles, reports, scientific meetings, university and Agency seminars, and USWRP workshops has had a significant impact in shaping future directions in atmospheric observing systems, synoptic-scale and mesoscale research. The most important application of our work is its contribution to the improvement of operational weather forecasting.

TRANSITIONS

My collaboration with NRL/Monterey and NOAA/NCEP scientists in experimental targeted observation programs, i.e., the ONR/NOAA North Pacific Experiment (NORPEX,1998) and the NOAA Winter Storm Reconnaissance Program (WSRP, 1999) has led to the current operational use of the NOAA/G-4 and USAF C-130 weather reconnaissance aircraft for winter season enhancement of observations over the relatively data-space North Pacific. My collaboration with Rolf Langland (NRL/Monterey) has contributed to the accelerated planning for the US Weather Research Program for The Northern Hemispheric Observing-System and Predictability Experiment (THOR*PEX*).

My work with Jim Doyle and William Thompson (NRL/Monterey) on the simulation and field study validation of complex mesoscale flows has been used to confirm the capabilities of the Navy operational mesoscale prediction system (COAMPS). These results are of critical value for development and verification of COAMPS.

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